DOI: https://doi.org/10.30795/jfootankle.2023.v17.1686

Systematic Review

Periarticular joint arthritis after ankle replacement vs. ankle arthrodesis. A systematic review

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Abstract

Objective: To complete a comprehensive literature review to determine the quantity and quality of literature supporting the incidence of IPJA after AA and TAR.

Methods: A comprehensive review was performed to determine the quantity and quality of literature supporting the incidence of IPJA after AA and TAR. After applying inclusion and exclusion criteria, 23 TAR and 19 AA studies were included.

Results: Only one high-quality level I was found, reporting 1.2% of IPJA after TAR. Majority of the studies were level IV and reported an incidence of subtalar arthritis of 0%-40%, talonavicular 2.8%-34%, and calcaneocuboid 2.8%-3.2% after TAR and an incidence of subtalar arthritis of 7.7%-100%, talonavicular 8.69%-11.6%, and calcaneocuboid of 22% after AA.

Conclusion: There is currently poor quality evidence supporting a higher rate of IPJA after AA compared to TAR. Also there is poor-quality evidence that supports IPJA as a complication of TAR; however, this is the current evidence on this topic. Better-quality long-term studies are required to make definitive and accurate conclusions on the incidence of IPJA.

Level of Evidence III; Therapeutic Studies; Systematic Review.

Keywords: Ankle joint; Arthrodesis; Disease progression; Incidence.

Introduction

End-stage ankle arthritis (ESAA) is a limiting condition that severely compromises the health-related quality of life[1-4]. Ankle arthrodesis (AA) and total ankle replacement (TAR) are currently the most accepted surgical treatments for ESAA. However, there is no clear consensus on whether TAR or AA provides the best clinical outcomes[5].

The introduction of TAR in 1970[6,7] opened a new opportunity for maintaining ankle function; however, AA remains a safe and effective surgical treatment for ESAA[8-21]. Some studies suggest that eliminating motion through AA will result in accelerated degeneration of the periarticular joints at mid or long-term follow-up[22-27]. Despite the benefit that ankle replacement may gain by preserving the tibiotalar motion, certain studies found ipsilateral periarticular joint arthritis (IPJA) after TAR surgery[7,28-54].

The aim of the present study is to systematically review the available literature to determine if there is evidence supporting IPJA as a complication after TAR and AA and a correlation between symptoms and further surgery to treat IPJA.

Study performed at the Queen Elizabeth II Health Sciences Center, Halifax, Nova Scotia, Canada.

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How to cite this article: Pasache Lozano RP, Morash J, O'Neill S, Glazebrook M. Periarticular joint arthritis after ankle replacement vs. ankle arthrodesis. A systematic review. J Foot Ankle. 2023;17(1):63-72.

Methods

Search strategy

A comprehensive review of the literature was performed on January 18, 2022, in the PubMed/Medline, Cochrane, and Web of Science databases using the search terms: ((“Arthroplasty, Replacement, Ankle”[Mesh]) AND “Arthritis”[Mesh]) AND “Joints”[Mesh] for total ankle replacement and (((“Ankle Joint”[Mesh]) AND “Arthrodesis”[Mesh]) AND “Arthritis”[Mesh]) AND “Joints”[Mesh] for ankle arthrodesis. The initial search criteria included all dates and types of publications, including retrospective and prospective studies, case reports, and reviews.

Selection criteria

Studies were included if: (1) they evaluated arthritis at least in one of the periarticular joints (subtalar, talonavicular, and calcaneocuboid) after TAR or AA (2) pre- and postoperative radiographs were reviewed. Studies were excluded if: (1) TAR and AA had concomitant periarticular joint fusions at the same stage or before surgery, (2) conversion from AA to TAR occurred, (3) non-English language articles, (4) systematic reviews that contained the studies already included in this review, (5) studies that did not specify the number of patients or joint affected with IPJA.

Two researchers independently reviewed the titles and abstracts and discussed inconsistencies until consensus was obtained; if necessary, a third researcher was consulted to make a final decision to prevent further bias. Next, two researchers independently performed a full-text read for inclusion. In case of disagreement, a consensus was reached on inclusion or exclusion by discussing with a third or fourth researcher until the final decision was determined. Frequencies of IPJA (subtalar, talonavicular, and calcaneocuboid joints) were calculated based on the number of patients treated with TAR from each study.

Level of evidence method

All articles were reviewed and assigned a Level of Evidence Classification from I to V according to the Journal of Bone and Joint Surgery “Levels of Evidence for Primary Research Question”[55].

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were used throughout this review for search, data extraction, and results analysis[56].

Results

The literature search yielded 643 relevant publications for TAR and 1295 studies for AA. After removing the duplicates, there were 562 TAR and 952 AA. Next, a title and abstract review for relevance was performed, and 512 TAR and 837 AA were excluded leaving 50 studies for TAR and 115 for AA.

After a full-text review, 27 TAR were excluded (ten German and one Korean studies, six incomplete-data studies, five studies with no or not mentioned preoperative radiographic assessment, and five systematic reviews that included studies already in this study). Ninety-six AA studies were excluded (sixty-eight other-language studies, three systematic reviews that included studies that were already eligible, seventeen incomplete-data studies with no number of patients or joints affected included, and eight studies with no or not mentioned preoperative radiographic assessment). Finally, 23 TAR and 19 AA studies were included for complete analysis (Figure 1).

Most studies were level IV (n = 18, 78.3% TAR, n = 17, 89.47% AA). The best quality study found was level I (n = 1, 4.3% TAR). There were also level II (n = 2, 8.7% TAR) and III (n = 2, 8.7% TAR, n = 2, 10.52% AA) studies.

Overall, the 23 TAR studies revealed a mean age of 62.32 years, and the 19 AA studies had a mean age of 57.1 years. The mean follow-up time was 6.2 years for TAR and 4.75 years for AA. The requirement for further periarticular fusion ranged from 5-13. 8 years after TAR and eight months to 10 years after AA.

Among the studies included, only three[29,30,37] addressed the IPJA as the main topic. The remaining studies performed overall research on outcomes and included IPJA as a complication.

To improve comprehension of the quality of studies, we divided the studies by level of evidence according to the Journal of Bone and Joint Surgery “Levels of Evidence for Primary Research Question”[55].

Level I study

Nunley et al.[49] performed a prospective randomized trial in 2019 comparing outcomes after a mobile-bearing (STAR) versus a fixed-bearing (SALTO TALARIS) TAR. Symptomatic subtalar arthritis was reported in one patient (1.2%) in the mobile-bearing group that required further subtalar fusion. Talonavicular and calcaneocuboid joints were not reported (Table 1).

Level II studies

Only two high-quality level II studies[35,37] were found for the TAR group (Table 1). No level II studies were found for the AA group. These reports did not consider the calcaneocuboid joint in the results. Overall in both studies, 194 ankles receiving TAR were found with a broad range of IPJA. Subtalar arthritis incidence was 8.8%-86%, and talonavicular 10.8%-70%.

Kerkhoff et al.[35] examined 134 ankles after TAR with mobile-bearing (STAR) prosthesis. The authors used the Kellgren and Lawrence classification system to report a total incidence of periarticular osteoarthritis of 19.6%, dividing into subtalar joint (8.8%) and talonavicular joint (10.8%) after pre- and postoperative radiographic assessment. A correlation with symptoms or requirement for further surgery was not considered in this study.

Mayich et al.[37] included 60 ankles and found an incidence of subtalar arthritis of 81%-86%, the majority were grade 1 and

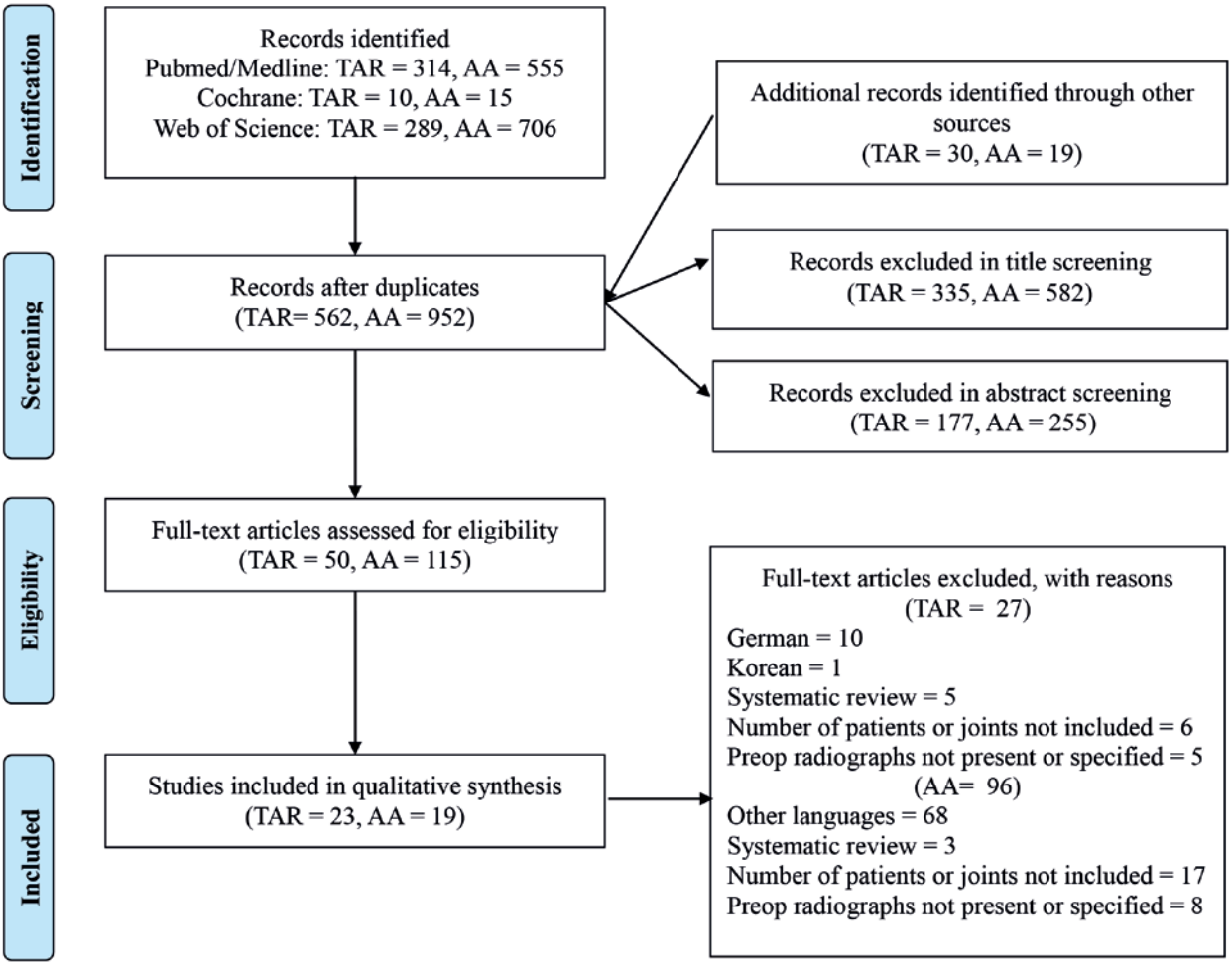

Figure 1. PRISMA flow diagram. The diagram illustrates the search process for published literature meeting the inclusion criteria for this study.

Table 1. Level I, II, III - TAR studies

Authors/ Year	Level	Age	Nº TAR	Follow-up	Implant	Joint	Symptoms	Surgery	Radiographic results
Nunley et al. 2019[49]	I	65 y (35-85) 43	41	4.5 y	STAR SALTO TALARIS	ST: 1.2%	ST pain 1.2%	ST fusion 1.2%	NR
Kerkhoff et al. 2016[35]	II	59y ± 12.5	134	7.5y	STAR	ST: 8.8% TN: 10.8%	NR	NR	KL
Mayich et al. 2013[37]	II	62y (33-90)	60	5y	NR	ST: 81%-86% TN: 62-70%	NR	NR	*KL*: ST: 0 = 8%; 1 = 39%; 2 = 39%; 3 = 11%; 4 = 4% TN: 0 = 29%; 1 = 40%; 2 = 21%; 3 = 6%; 4 = 4%
Marks 2019[50]	III	65.3y (49.4-81.6)	50	4.9y (0.9-8.6)	SALTO TALARIS	ST: 2%	ST pain 2%	ST fusion 2%	NR
Krause et al. 2011[44]	III	64.2y (36-88)	114	38.7m (25-68)	Agility HINTEGRA STAR Mobility	NR	NR	NR	*KL:* Postop: ST: 1.75% (0 to grade 2: 0.88%, 0 to grade 3: 0.88%) TN: 0.88% (0 to grade 2: 0.88%)

* y: years, m: months, ST: subtalar, TN: talonavicular, NR: not reported, KL: Kellgren and Lawrence scale, TAR: Total Ankle Replacement

2, and talonavicular arthritis of 62%-70%, mainly grade 1 of the Kellgren and Lawrence scale.

Level III studies

TAR

Two level III studies[44,50] reported IPJA after TAR and matched the inclusion criteria (Table 1).

Incidence of IPJA

Marks[50] studied 50 patients after TAR with SALTO TALARIS, and 2% of them developed symptomatic subtalar arthritis that required subtalar fusion. Talonavicular and calcaneocuboid joints were not reported.

Progression of IPJA

Krause et al.[44] reported the progression of IPJA using the Kellgren and Lawrence scale in 114 ankles with different types of ankle prostheses. Subtalar arthritis progression was 0.88% each from grades 0 to 2 and 0 to 3. Talonavicular progression was also 0.88% from grade 0 to 2.

AA

Two level III studies[21,44] were identified (Table 2). Both studies reported progression of IPJA after 73 ankle fusions showing a progression of 4.2%-15% for subtalar joint, 2.1% for talonavicular joint, and 3.84% for calcaneocuboid joints.

The studies were analyzed on different scale grading systems. Krause et al.[44] reported the progression of osteoarthritis with the Kellgren and Lawrence scale. Subtalar arthritis progression was 2.1% each from grade 0 to 2 and 0 to 3. Talonavicular progression was 2.1% from grade 1 to 3. Thomas et al.[21] studied the progression with Kellgren and Moore scale, finding IPJA progression rates of 15% and 3.84% from grade 2 to 5 in the subtalar and calcaneocuboid joints, respectively.

Level IV studies

TAR

Eighteen level IV studies[28-32,36,38,40,41,43,45-48,51-54] were included (Table 3).

Incidence of IPJA

Fifteen studies[28,30-32,38,40,41,45-48,51-54] reported the incidence of IPJA. Only three[28,41,46] reported total adjacent joint arthritis of the three joints studied (subtalar, talonavicular, and calcaneocuboid) with a result range of 0%-14.3%. Overall, in 995 ankles following TAR, the incidence of subtalar arthritis was 0-40%, talonavicular arthritis 2.8%-34%, and calcaneocuboid arthritis 2.8%-3.2%.

Three of these studies[28,32,45] found a correlation between symptoms and subtalar joint arthritis in 1.47%-1.7% of patients. The need for additional fusion was reported in eight studies[28,32,38,41,45,46,48,52] with a wide range of timing from 35 months to 13.5 years after TAR. One of the studies[38] showed a higher amount of subsequent joint fusions than arthritis incidence reported due to failed replacement surgery, so we excluded that data in these results. Two studies[43,46] identified no requirement for further surgery, and one reported no IPJA in their results.

Dekker et al.[30] compared three different prostheses in 140 ankles after TAR and reported subtalar arthritis of 40% and talonavicular of 34%, with considerably fewer cases that needed fusion due to painful arthritis (subtalar 11.4% and talonavicular 1%). Regarding the preexisting IPJA, there was an incidence of 40% and 53% grade 1 for subtalar and talonavicular joints.

Saltzman et al.[54] evaluated the incidence of IPJA in a mean follow-up of 4.2 years on 37 patients finding 5% subtalar, 16% talonavicular, and 44% calcaneocuboid joints newly onset arthritis after STAR-TAR.

Progression of IPJA

Seven studies[28-30,36,43,48,54] reported osteoarthritis progression of IPJA after TAR. Four[28,30,48,54] reported the incidence and progression of IPJA. Among 1111 ankles, 14.3%-38% IPJA progression was reported, ranging from 4.8%-59%, 6.4%-38%, and 3.2%-38% in the subtalar, talonavicular, and calcaneocuboid joints, respectively.

Sokolowski et al.[29] reported on secondary subtalar IPJA after TAR, 671 were included, 37 (4%) had subtalar IPJA that required a secondary subtalar fusion. Evaluation of pre- and postoperative radiographs was performed, 99% had previous TAR subtalar arthritis with a correlation of 2% of symptomatic

Table 2. Level III - AA studies

Authors/Year	Age	Nº AA	Follow-up	Joint	Symptoms	Surgery	Radiographic results
Krause et al. 2011[44]	58.5y (28-82)	47 (22 open-22 arthroscopic)	36.5m (28-109) OA: 5y	NR	NR	None	*KL*: Postop ST: 4.2% (0 to grade 2: 2.1%, 0 to grade 3: 2.1%) TN: 2.1% (1 to grade 3)
Thomas et al. 2006[21]	54y	26	44m	NR	NR	NR	*KM:* Progression ST: 15% CC: 2 to 5 = 3.84%

* y: years, m: months, ST: subtalar, TN: talonavicular, CC: calcaneocuboid, NR: not reported, KL: Kellgren and Lawrence scale, KM: Kellgren and Moore scale, AA: Ankle Arthrodesis, OA: Osteoarthritis

Table 3. Level IV - TAR studies

Authors/ Year	Age	Nº TAR	Follow up	Implant	Joint	Symptoms	Surgery	Radiographic results
Sokolowski et al. 2019[29]	58.8y (33.1-74.6)	671	5y (0.1-17)	H3	ST: 99% preop	ST pain 2%	ST fusion 4% (1.9% not for pain) ST fusion: 5y (0.3-10)	*KL:* Preop: Without ST fusion: 0 = 0%, 1 = 8%, 2 = 30%, 3 = 44%, 4= 18%; With ST fusion: 0 = 18%, 1 = 24%, 2 = 29%, 3 = 29%, 4 = 0%. Postop: Without ST fusion: 0 = 0%, 1= 2%, 2 = 19%, 3 = 51%, 4 = 28%; With ST fusion: 0 = 18%, 1 = 21%, 2 = 23%, 3 = 26%, 4 = 12%. Progression: 32%: Without ST fusion: 1 grade = 30%, 2 grades = 2%; With ST fusion: 1 grade = 18%, 2 grades = 3%.
Palanca et al. 2018[28]	73.7y (51.3-92.9)	21	15y	STAR	T: 14.3% ST: 4.8% TN:6.4% CC:3.2%	ST pain 1.6%	ST fusion 1.6% ST fusion: 13.8y	*KL*: Progression 1 grade = ST 3.2%, TN 3.2%, CC 1.6% 2 grades = ST 0%, TN 3.2%, CC 1.6% 3 grades = ST 1.6%, TN 0%, CC 0%
Barg et al. 2018[48]	67y	55	26.6m ± 4.2	Zimmer Trabecular Metal	Preop ST: 67.2%, TN: 36.3%. Postop: ST: 71%, TN: 36.4%	NR	TN fusion post TAR 1.8%	*KL:* Preop: ST: 0 = 32.7%, 1 = 52.7%, 2 = 3.6%, 3 = 1.8%, 4 = 0% TN: 0 = 63.6%, 1 = 23.6%, 2 = 1.8%, 3 = 1.8%, 4 = 1.8% Postop: ST: 0 = 29.1%, 1 = 56.4%, 2 = 5.5%, 3 = 0% , 4 = 0% TN: 0 = 63.6%, 1 = 25.5%, 2 = 1.8%, 3 = 0%, 4 = 0%
Eckers et al. 2018[51]	43 y (27.4-57.6)	17	9.6 (3.3-17.8)	Agility HINTEGRA STAR Mobility	ST: 17.64%	NR	NR	NR
Dekker et al. 2017[30]	70.5y (31-91)	140	6.5y (5.0-8.9)	SALTO TALARIS STAR INBONE	ST: 40% TN: 34%	ST pain 11.4% TN pain 1%	ST fusion 11.4% TN fusion 1%	*KL*: Preop: ST:0 = 20%, 1= 40%, 2 = 21%, 3 =19%; TN: 0 = 31%, 1 = 53%, 2 = 8%, 3 = 8% Postop: ST: 1 grade = 27%, 2 grades = 1%, TN: 1 grade = 31%, 2 grades = 1% Progression of 1 grade: SALTO TALARIS: ST 29%, TN 38.5% STAR: ST 22%, TN 23.1% INBONE: ST 27%, TN 29.5%
Frigg et al. 2017[38]	58y (38.0-81.8)	50	14.6y(12.9-16.4)	STAR	ST: 6%	NR	ST fusion 12% TN fusion 4%	NR
Stewart et al. 2017[52]	61.9 y	72	81.1m (60-115)	SALTO TALARIS	ST: 2.8%	NR	ST fusion 2.8%	NR
Chao et al. 2015[40]	68.6 y (53.2-85.4)	23	36m(24-49)	SALTO TALARIS	ST: preop 65.2%, postop 100%	ST pain 0%	ST fusion 21.7%	Preop: ST: None = 34.8%, Mild = 39.1%, Mod = 4.3%, Sev = 17.3%. Postop: ST: None = 0%, Mild = 69.5%, Mod = 0%, Sev = 8.7%.
Rodrigues-Pinto et al. 2013[32]	55.6y (24-81)	119	38.7m (18-72) OA: 11.5m	SALTO TALARIS	ST: 1.7%	ST pain 1.7%	ST fusion 1.7%	NR
Choi et al. 2013[41]	63y (40-78) 62y (36-77)	77	53m (24-76) 32m (24-45)	HINTEGRA Mobility	HINTEGRA ST: 3.1% Mobility T: 8.6%, ST: 2.8% TN: 2.8% CC: 2.8%	NR	None	NR
Mann et al. 2011[43]	61.4y	55	9.1y (2.6-11) OA: 9.1y	STAR	T: 38% ST: 20% TN: 13% CC: 4%	None	None	Progression: ST: 1 grade = 18.2%, 2 grades = 1.8% TN: 1 grade = 10.9%, 2 grades = 1.8% CC: 1 grade = 3.6%
Saltzman et al. 2010[54]	64y	37	4.2 y (2.2-5.9)	STAR	preop: ST 95% TN 82% CC 21% postop: ST:100%TN 98% CC 65%	NR	NR	*KL*: Preop: ST: 0 = 5%, 1 = 32%, 2 = 41%, 3 = 22%, 4 = 0%; TN: 0 = 19%, 1 = 46%, 2 = 30%, 3 = 3%, 4 = 3%; CC: 0 = 78%, 1 = 16%, 2 = 5%, 3 = 0%, 4 = 0%. Postop: ST: 0 = 0%, 1 = 0%, 2 = 49%, 3 = 38%, 4 = 14%; TN: 0 = 3%, 1 = 16%, 2 = 57%, 3 = 22%, 4 = 3%; CC: 0 = 35%, 1 = 43%, 2 = 22%, 3 = 0%, 4 = 0%. Progression: ST: 1 grade = 59%, 2 grade = 14%, TN: 1 grade = 38%, 2 grades = 19%, CC: 1 grade = 38%, 2 grades = 11%.

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Table 3. Level IV - TAR studies

Authors/ Year	Age	Nº TAR	Follow up	Implant	Joint	Symptoms	Surgery	Radiographic results
Wood et al. 2008[31]	NR	200	88m (60-156)	STAR	ST: 15%	NR	NR	*KL*: Preop: ST: 4 = 45.5% Postop: New cases: ST 15%
Ali et al. 2007[47]	69y (58-84)	35	5y (3-150m)	Buechel-Pappas	ST: 5.7%	NR	NR	NR
Kopp et al. 2006[58]	63y (32-85)	40	44.5m (26-64)	Agility	0%	NR	None	NR
Knecht et al. 2004[36]	61y (27-83)	132	9y OA: 7.2y (2-14)	Agility	Preop: ST: 100% TN: 100%	NR	ST fusion 2.3% Triple arthrodesis 2.3%	*KM:* Preop: ST: 1-2-3 = 85%, 4-5 = 15%; TN: 1-2-3 = 87%, 4-5 = 13%. Postop: ST: 1 = 15%, 2 = 33%, 3 = 31%, 4 = 11%, 5= 27%; TN: 1 = 22%, 2 = 41%, 3 = 21%, 4 = 11%, 5 = 22%. Progression: ST: 19%; TN: 15%
Valderrabano et al. 2004[45]	56.1y (22-85)	68	3.7y (2.4-6.2)	STAR	ST: 1.47%	ST pain 1.47% Symptoms: 6m	ST fusion 1.47% ST fusion: 35m	NR
Kofoed et al. 1998[53]	61 y (34-76)	41	9y (6-14)	NR	ST: 0%	NR	NR	NR

* y: years, m: months, ST: subtalar, TN: talonavicular, CC: calcaneocuboid, T: subtalar, talonavicular and calcaneocuboid, NR: not reported, KL: Kellgren and Lawrence scale, KM: Kellgren and Moore scale, TAR: Total Ankle Replacement

arthritis. Time from primary TAR to subtalar joint fusion due to IPJA was 5.0 (0.3-10) years.

Dekker et al.[30] postoperative follow-up also reported osteoarthritis progression, showing 1 grade progression in 27% of subtalar joint and 31% of talonavicular. There was no difference in the progression among the three kinds of prostheses.

Saltzman et al.[54] compared pre- and postoperative IPJA using the Kellgren and Lawrence scale, finding progression of 59%, 38%, and 38% of 1 grade in subtalar, talonavicular, and calcaneocuboid joints, respectively.

AA

Seventeen level IV studies[8-13,15-18,20,54,57-61] were analyzed after researching IPJA after AA (Table 4).

Ten studies[10,12,13,15,16,20,58-61] reported pain in the adjacent joints. One[16] reported no association of osteoarthritis with pain, and the remaining showed a range of 6.25%-39.13%. Furthermore, ten studies[10,12,13,15,17,18,57,59-61] reviewed the need for further surgery; subtalar fusion was reported in 1.61%-25%, talonavicular 0.95%-3.84%, triple arthrodesis 0.95%. One study[18] was the only one that reported no surgery due to IPJA.

Incidence of IPJA

Ten level IV studies[10,11,13,17,20,54,57,58,60,61] reported the incidence of IPJA after AA. Three studies[12,18,54] reported the incidence and progression of IPJA. A broad range of subtalar arthritis of 7.7%-100% was reported, the talonavicular joint of 8.69%-11.6%, and calcaneocuboid joint had 22%.

Progression of IPJA

Eight reports[8,9,12,15,16,18,54,59] analyzed the osteoarthritis progression of IPJA. Subtalar joint progression was 30%-47.82%, talonavicular joint 8.69%-48.5%, and calcaneocuboid joint 18.18%-26%.

Jones et al.[8] performed a study on 101 ankles classifying subtalar and talonavicular arthritis in both Kellgren and Lawrence and Van Dijk scales, with 15% of osteoarthritis progression on the Kellgren and Lawrence scale and 4% on the Van Dijk scale.

Saltzman et al.[54] compared pre- and postoperative IPJA using the Kellgren and Lawrence scale, finding progression of 47%, 47%, and 26% of 1 grade in subtalar, talonavicular, and calcaneocuboid joints, respectively.

Discussion

Nowadays, AA and TAR are surgical options for the management of ESAA. While AA has been considered the gold standard for several years and is still one of the main options, TAR has improved with better prosthesis development[5]. For many years, mid or long-term complications had been reviewed for these procedures, exposing potential higher incidence of IPJA after AA with no conclusive results in the literature due to many confounding factors that may suggest but not confirm this statement.

Furthermore, there is no conclusive evidence in the literature to confirm or deny the presence of IPJA after TAR which has not been implied as a possible complication after this procedure. For that reason, the aim of this review was to perform a systematic review to have a documented basis for incidence and/or progression after TAR and AA.

Table 4. Level IV - AA studies

Authors/Year	Age	Nº AA	Follow-up	Joint	Symptoms	Surgery	Radiographic results
Jones et al. 2017[8]	61.1 y (35.8-79.6)	101	86 m (24-247)	NR	NR	NR	*KL:* Progression: 15% ST: 0 = 47.5%, 1 = 16.8%, 2 = 3.96%, 3= 0.99% TN: 0 = 59.1%, 1 = 5.94%, 2 = 2.97%, 3 = 0.99% *VD:* Progression: 4% ST: 0 = 47.5%, 1 = 18.8%, 2 = 2.97%, 3 = 0% TN: 0 = 60.4%, 1 = 5.94%, 2 = 2.97%, 3 = 0%
Morasiewicz et al. 2017[9]	Ilizarov: 43y (17-66) Internal fixation: 47y (17-67)	62 (29 Ilizarov - 33 internal fixation)	Ilizarov 43m (24-108). Internal fixation 45m (24-104)	Ilizarov T: 65.5% Internal fixation T: 100%	NR	NR	Ilizarov: Preop: T = 48.3%, ST = 48.3%, TN = 34.5%, CC = 34.5%. Postop: T = 65.5%, ST= 65.5%, TN= 48.3%, CC = 34.5%. Internal fixation: Preop: T = 81.8%, ST = 75.8% , TN = 33.3%, CC = 30.3%. Postop: T = 100%, ST = 96.9%, TN = 81.8%, CC = 66.6%.
Flint et al. 2016[10]	60y (29-84)	60	1.1y (0.3-4)	ST: 20%	Hindfoot pain 12% Midfoot pain 5%	ST fusion 1.66%	NR
Lee et al. 2016[12]	62.4y (39-79)	23	41m (15-80)	Preop: ST: 96.65% TN: 81.8%	ST pain: 39.13%	ST fusion 4.34%	Progression: Isolated ST = 47.82%, TN = 8.69%, ST + TN = 18.39%. Postop: New TN = 8.69%
Jain et al. 2015[11]	59.4y (27-80)	52	32.1m (8-78)	ST: 11.54% TN: 3.85%	NR	NR	NR
Vaughan et al. 2015[13]	68.5y (59-80)	8	58.5m (24-100)	ST: 25%	ST pain 25%	ST fusion 25% ST fusion: 34-89 m	NR
Strasser et al. 2012[15]	74.5y ± 3.7	30	8.5 y ± 1.7	NR	ST pain 36.6%	ST fusion 6.66% ST fusion: 9-10y	*KL*: Preop: ST: 1 = 40%, 2 = 46.66%, 3 = 6.66% Progression: ST: 36.6%
Hendrickx et al. 2011[16]	47y	66	9y	Preop: ST: 91% TN: 77.2% CC: 10.6% Progression: ST: 30.3% TN: 28.78%, CC: 18.18%	OA not correlated with pain	NR	*VD*: Progression: ST: 0 to 1 = 2.7%, 0 to 2 = 1.3%, 0 to 3 = 0%, 1 to 2 = 20%, 1 to 3 = 9.3%, 2 to 3 = 5.3% TN: 0 to 1 = 12.1 %, 0 to 2 = 0%, 0 to 3 = 0%, 1 to 2 = 16.7%, 1 to 3 = 0%, 2 to 3 = 0% CC: 0 to 1 = 15.2%, 0 to 2 = 0%, 0 to 3 = 0%, 1 to 2 = 3%, 1 to 3 = 0%
Dannawi et al. 2011[17]	63y (32-84)	62	63m (21-92)	ST: 24.19%	NR	ST fusion 1.61%	*KL:* ST: 2 = 17.74% , 3 = 3.22%, 4 = 3.22%
Zwipp et al. 2010[18]	53y (34-69)	72	5.9y (4.8-7.8)	Preop ST: 35% TN: 18%	NR	None	*BH:* New postop: ST: 17%, TN: 11% Progression: ST: 30%, TN: 19%
Saltzman et al. 2010[54]	56y	23	4.2 y (2.2-5.9)	Preop: ST: 94%, TN: 92%, CC: 45%. Postop: ST: 100%, TN: 100%, CC: 67%	NR	NR	*KL*: Preop: ST: 0 = 5%, 1 = 25%, 2 = 32%, 3 = 32%, 4 = 5%; TN: 0 = 11%, 1 = 50%, 2 = 32%, 3 = 5%, 4 = 5%; CC: 0 = 53%, 1 = 40%, 2 = 5%, 3 = 0%, 4 = 0% Postop: ST: 0 = 0%, 1 = 0%, 2 = 42%, 3 = 38%, 4 = 21%; TN: 0 = 0%, 1 = 17%, 2 = 63%, 3 = 16%, 4 = 5%; CC: 0 = 33%, 1 = 46%, 2 = 16%, 3 = 5%, 4 = 0% Progression: ST: 1 grade = 47%, 2 grade = 11%; TN: 1 grade = 47%, 2 grades = 11%; CC: 1 grade = 26%, 2 grades = 11%
Gougoulias et al. 2007[20]	Group A: 51.8 ± 13.5y (18-81) Group B: 57.6 ± 14.23y (23-80)	78	21.1m (6-68)	ST: 7.7%	ST pain 7.7%	NR	NR
Winson et al. 2005[57]	57.2y (20-86)	105	65m (18-144) Surgery: 48 m	ST: 42.85% Grade 3 or 4	NR	ST fusion: 5.71%, TN fusion: 0.95%, Triple arthrodesis: 0.95%, TTC 0.95%	*KL* Preop: ST: 1 and 2 = 20.95%, 3 = 26.66%, 4 = 5.71%
Kopp et al. 2004[58]	42y (17-82)	46	7.3 y (2-20)	ST: 21.73%	ST pain 10.86%	NR	NR
Takakura et al. 1999[59]	57.9 y (25-79)	43	7.2y (2.4-14.11)	ST: 32.5% TN: 11.6%	ST pain 2.32%	ST fusion 2.32% ST fusion:4y	Progression ST: 0 to 1 = 6.97%, 1 to 2 = 18.6%, 2 to 3 = 4.65%
Felix et al. 1998[60]	60 y (28-73)	26 (14AA-12 TTC)	5y (2-8) Surgery: 8m	ST: 84.61%	ST + TN pain 3.84%	ST+ TN fusion 3.84%	ST postop: Mild: 7.69%, Moderate: 38.46%, Severe: 38.46%
Dennis et al. 1988[61]	50.8 y (23-72)	16	15.1m (3-25)	NR	ST pain 6.25%	ST fusion 6.25% ST fusion: 2y	NR

y: years, m: months, ST: subtalar, TN: talonavicular, CC: calcaneocuboid, T: subtalar, talonavicular and calcaneocuboid, OA: osteoarthritis, AA: Ankle Arthrodesis, NR: not reported, KL: Kellgren and Lawrence scale, VD: Van Dijk scale, BH: Bargon and Henkemeyer scale, TTC: Tibiotalocalcaneal

Onggo et al.[62] developed the latest systematic review and meta-analysis of outcomes after TAR; however, the incidence or progression of IPJA after TAR was not specified. Ling et al.[63] performed a systematic review on IPJA after AA, reporting 24 studies with a wide range of incidence between 24% to 100% for the subtalar joint and 18% to 77% for the talonavicular joint (mainly level IV of evidence). In our review, they were no high-quality level studies for ankle fusion. The highest quality was level III, with just two studies. The level IV studies showed similar wide ranges of 7.7%-100% for subtalar, 8.69%-11.6% for talonavicular, and 22% for calcaneocuboid reported in just one study[54]. Only one high-quality level I study reported briefly on subtalar joint arthritis after TAR, with 1.2% of incidence after 4.5 years of the procedure.

Also, two level II studies reported TAR with a broad range of IPJA. Nevertheless, in this group, it is important to highlight that the study performed by Mayich et al.[37] showed a higher incidence of IPJA; however, it reported a poor intra- and interobserver reliability of the Kellgren and Lawrence scale in these joints.

Another finding of our study is that even if there is a high incidence of IPJA after AA, the symptomatic patients are less than one-third of the cases, and fewer require further surgery due to IPJA pain. Similar was found in the TAR group, with a minor incidence of IPJA but still present. Thus, it is important to correlate the radiographic and clinical assessment when evaluating these patients since a significant amount of patients have non-symptomatic IPJA.

The follow-up was variable in both groups, and the few long-term studies had a higher incidence of IPJA, another reason for the wide range of incidence found.

The main limitation of our review is the quality of the studies found in the literature, only one level I study was found[49], and unfortunately, this study did not assess specifically our topic, which could decrease the reliability of the study in this regard; also there were two level II studies for TAR, these reported on incidence but not on progression.

Our study also shows that there are cases of IPJA after TAR that were not previously reported. This information will lead us to question whether the IPJA is caused by the implant change in the biomechanics or is part of an ongoing degenerative disease. Regarding this aspect, there is still no consensus on a cause for IPJA. This is likely multifactorial rather than just the arthrodesis or the replacement.

This study demonstrates that the literature provides limited evidence on IPJA and could be a potential topic of study in the future with the population increase for both procedures to complete the outcome expectations.

Conclusions

There is poor quality evidence that supports a higher rate of IPJA complication after TAR and AA. The literature does provide some support that IPJA occurs after TAR with a lower incidence and progression than AA. There are insufficient high-quality studies to determine the IPJA accurate rate, thereby would be classified as "I" according to the Journal of Bone and Joint Surgery "Grades of recommendation" [64].

It is important to mention that despite the quality of the studies identified, this is the best available evidence on this topic and will be supportive evidence for future high-quality clinical trials.

Authors' contributions: Each author contributed individually and significantly to the development of this article: RPPL *(https://orcid.org/0000-0002-2518-637X) Conceived the study, performed data collection, bibliographic review and interpreted the results, finally performed the formatting of the article; JM *(https://orcid.org/0009-0009-4346-3252) Participated in the review process and collaborated with data collection as necessary; SON *(https://orcid.org/0009-0002-4650-8961) Collaborated with the bibliographic review and data collection; MG *(https://orcid.org/0000-0002-4608-6191) Conceived and planned the activities that led to the study and approved the final version. All authors read and approved the final manuscript.*ORCID (Open Researcher and Contributor ID).

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